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G1U UR1124
G4H HNEE HNEJ H1A H13D H14A H14B H14D H14G H60
U1S S2146 S2177

(56) Documents cited
GB 2102169 A GB 2098820 A EP 0205779 A2
EP 0160838 A2 EP 0124434 A1

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INT CL[5] G06M

(54) **Reading meters**

(57) A meter comprises a disc 12 which rotates at a velocity proportional to the rate of consumption of electricity, gas etc. One face of the disc 12 is reflective except for a surface 31 which is non-reflective. A sensor 13 having an infra-red emitting diode and an associated phototransistor is mounted relative to the disc 12 and a count is electronically stored of the number of times the disc interrupts the beam of infra-red radiation. This information can be transmitted by wireless to a receiver.

A second non-reflective surface may be provided so that reverse rotation of the disc 12, indicating tampering, may be detected. When the meter casing is closed an electrical switch is closed, tampering with the casing opening the switch.

The meter may transmit information to a van. Alternatively a plurality of meters may transmit information to a central unit mounted on a lamp-post, the central unit transmitting information to the van. In a further embodiment a meter may transmit information to a central unit via one or more intermediate meters.

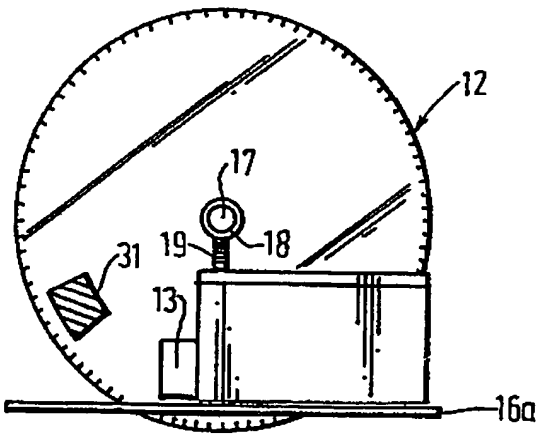

FIG.4

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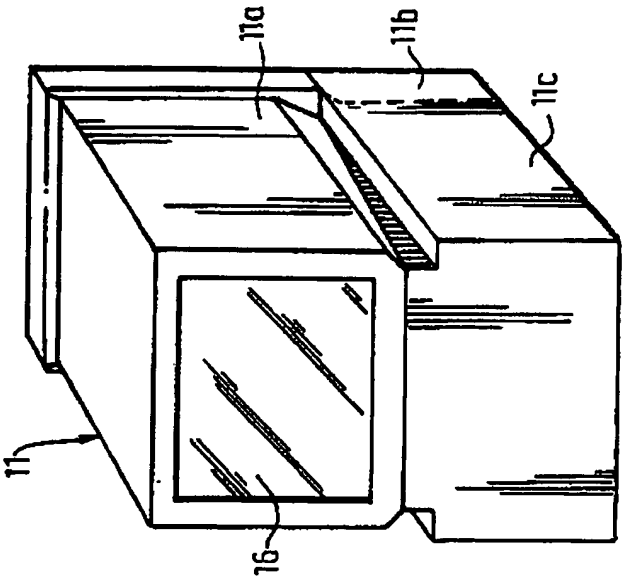


FIG.3

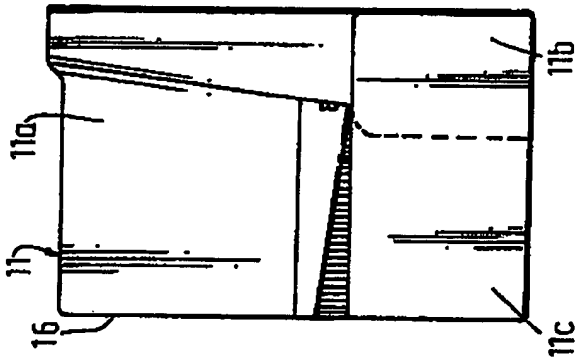


FIG.2

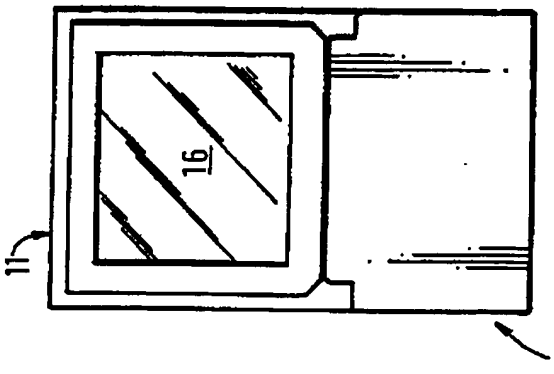


FIG.1

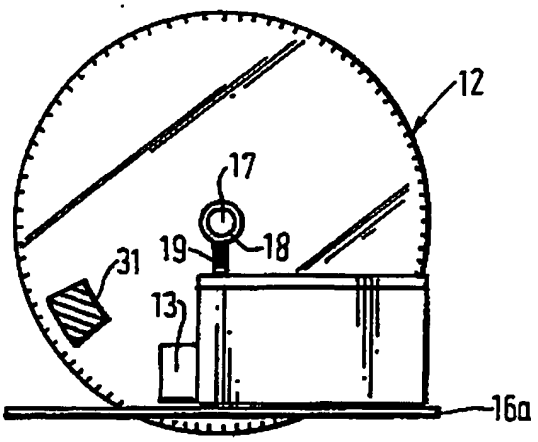


FIG.4

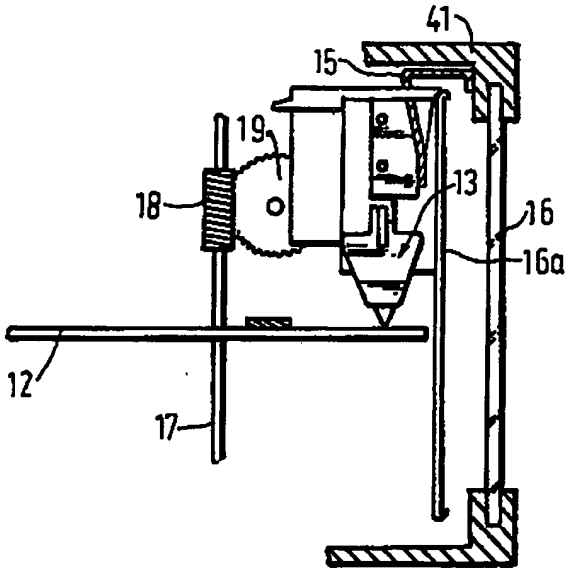


FIG.5

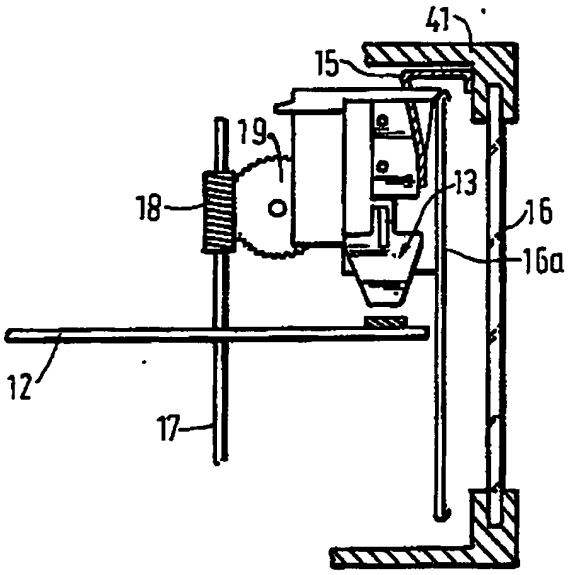


FIG.6

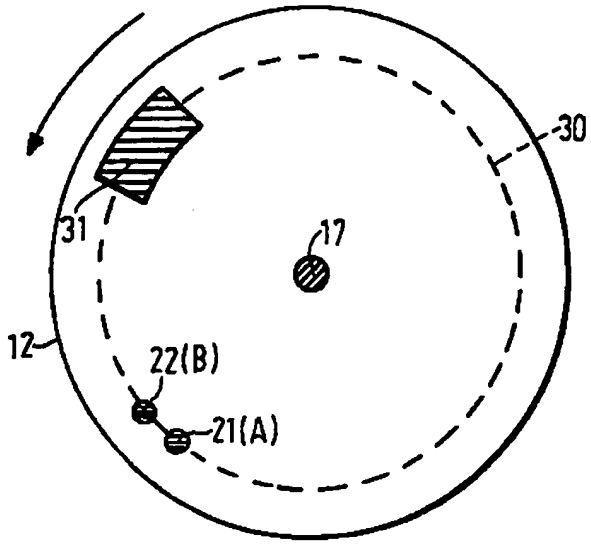


FIG.7

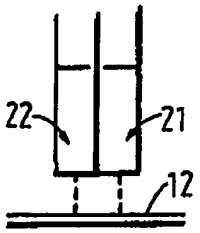


FIG.8

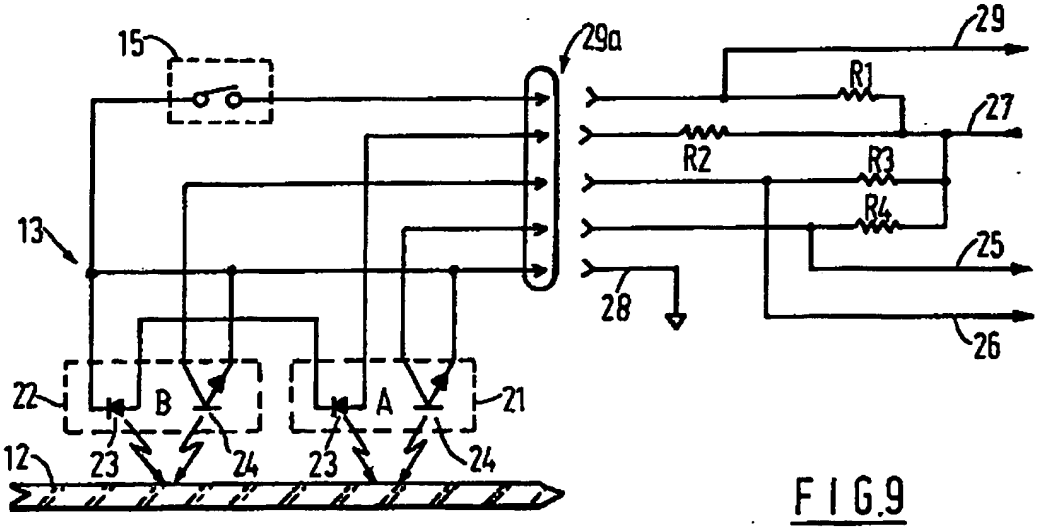


FIG.9

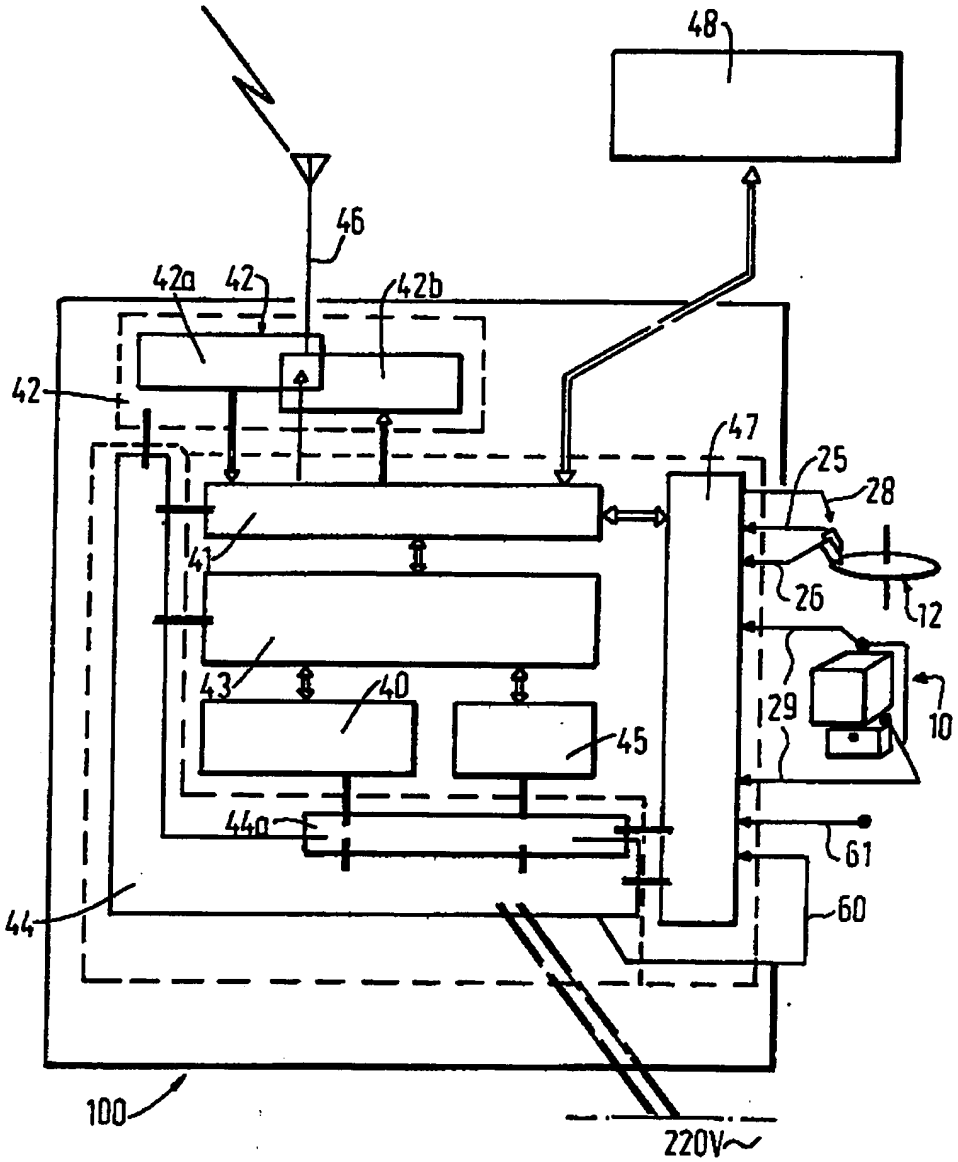
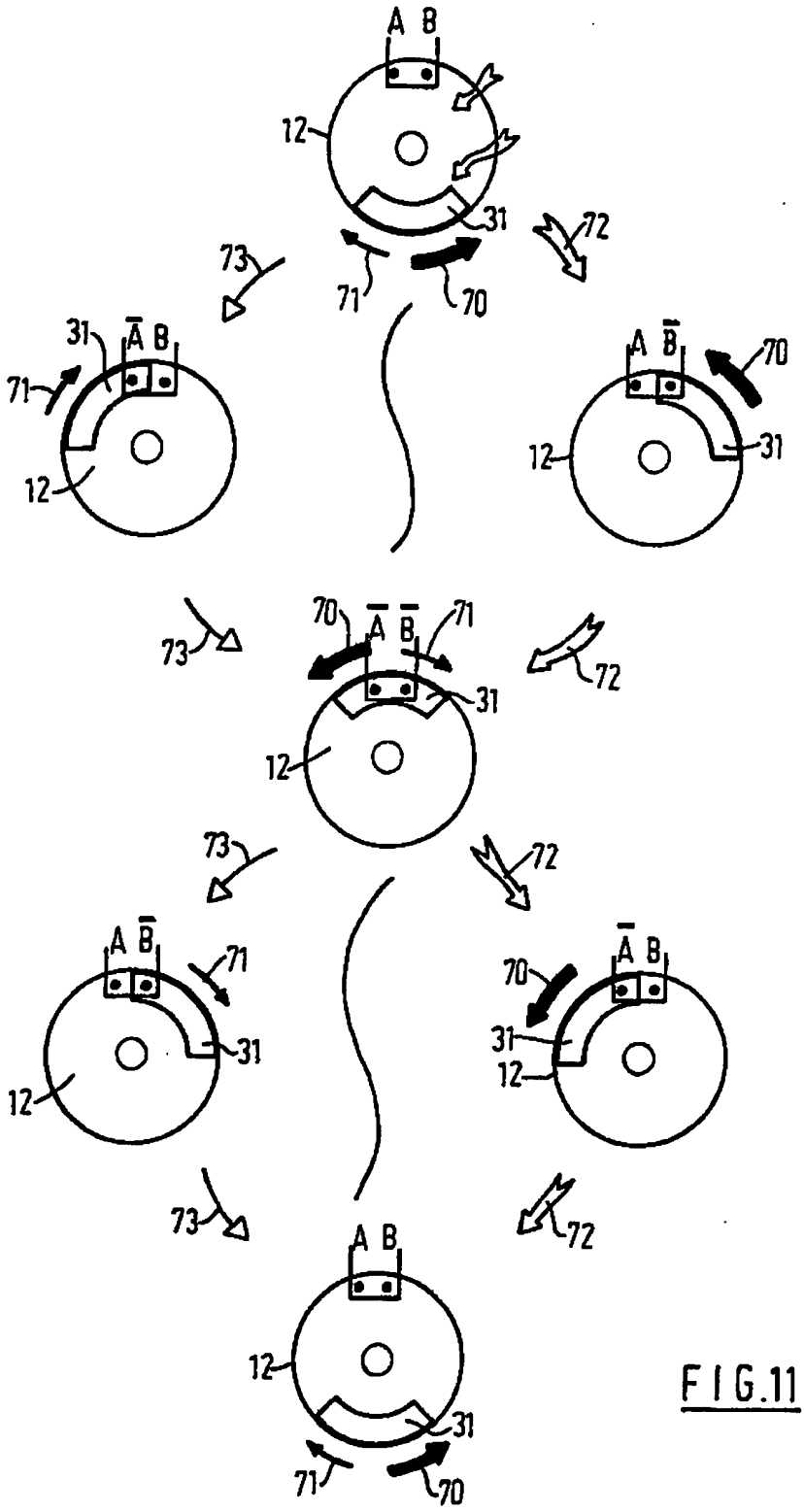

48
46
42a
42
42b
42
47
25
28
41
26
12
43
40
29
10
45
44a
61
44
60
100
220V~

FIG.10


A B
12
31
72
73
71
70
31
Ā B
71
12
A B̄
70
12
31
70
Ā B̄
71
73
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31
12
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12
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71
70

FIG.11

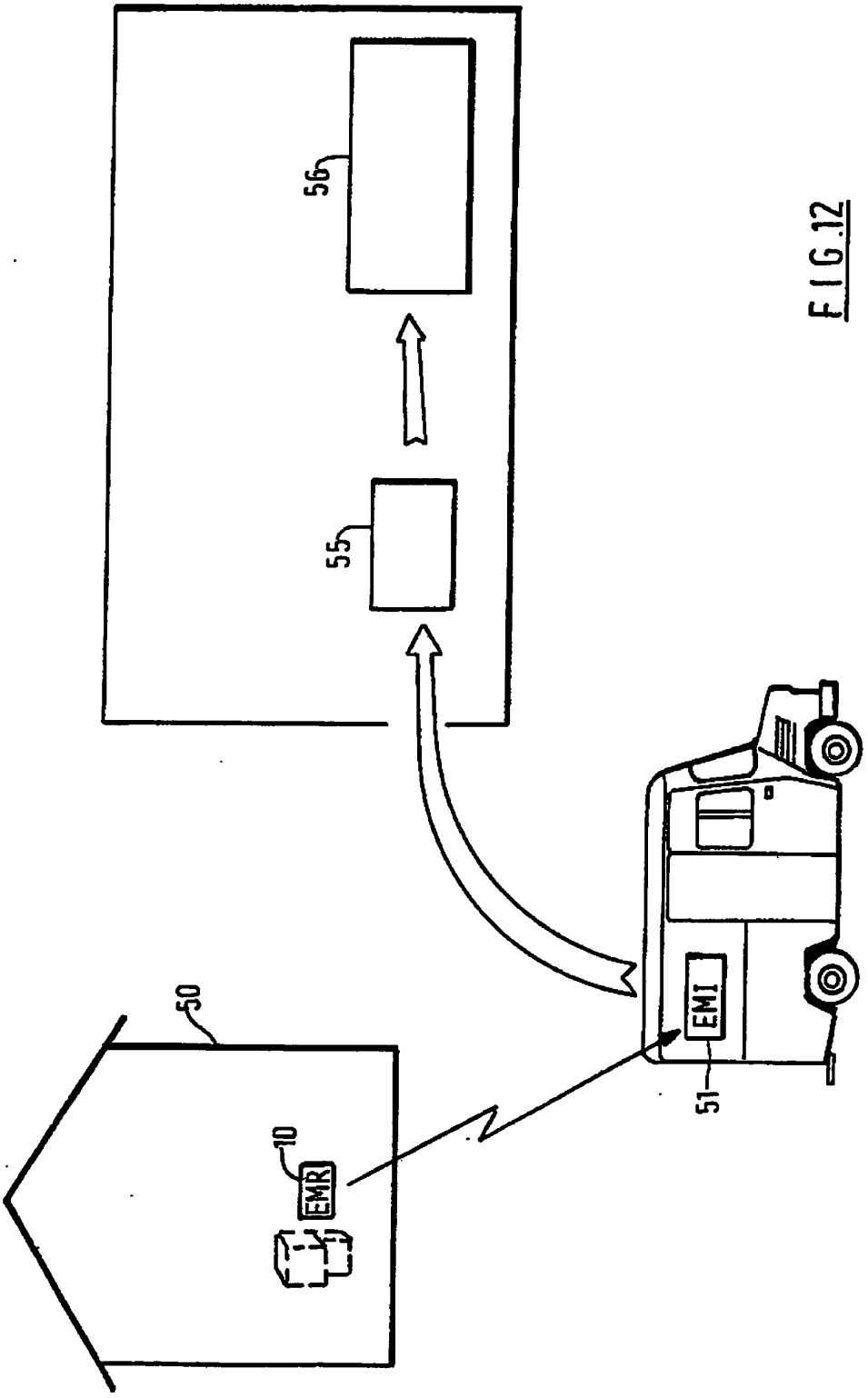

FIG.12

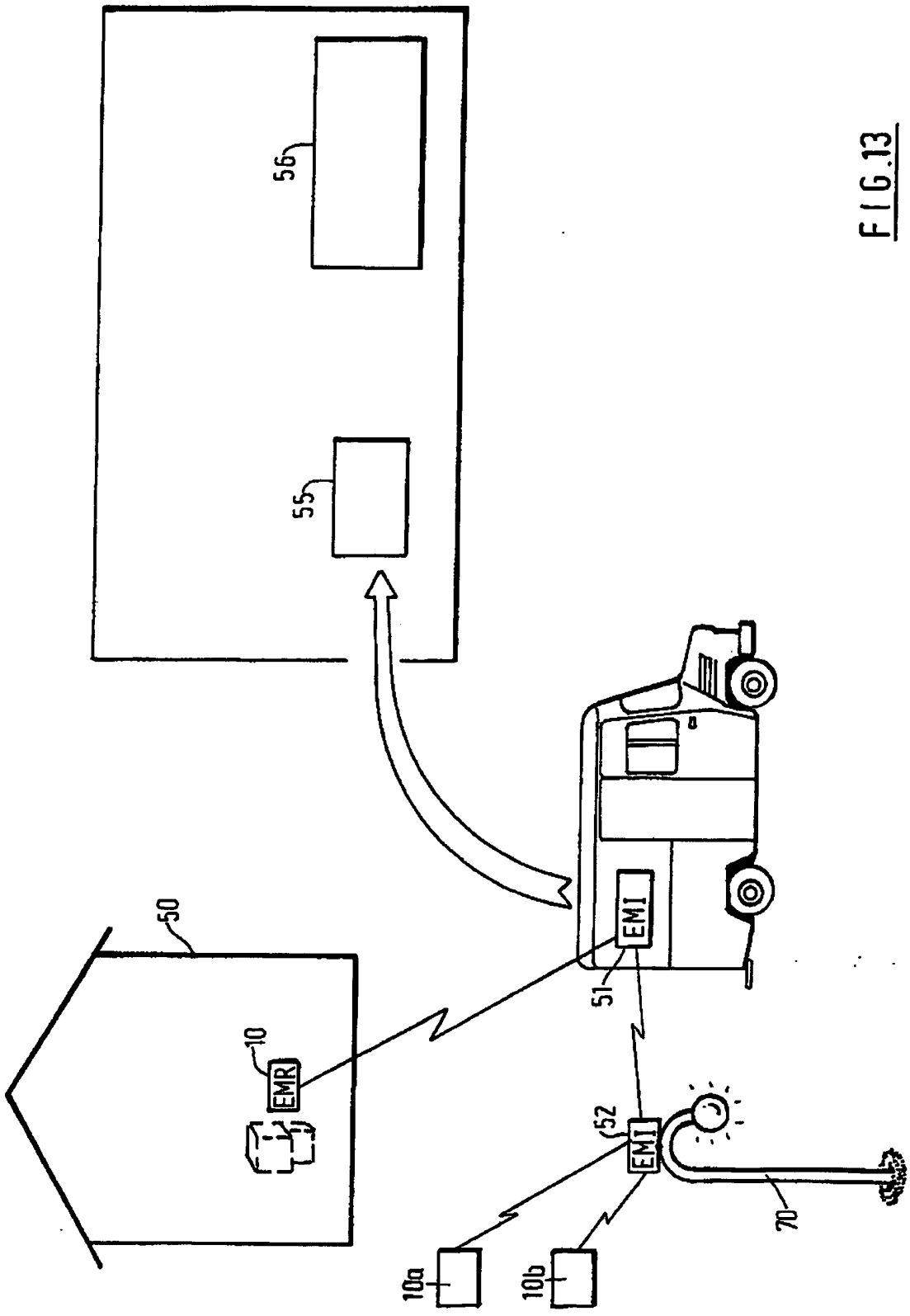

FIG.13

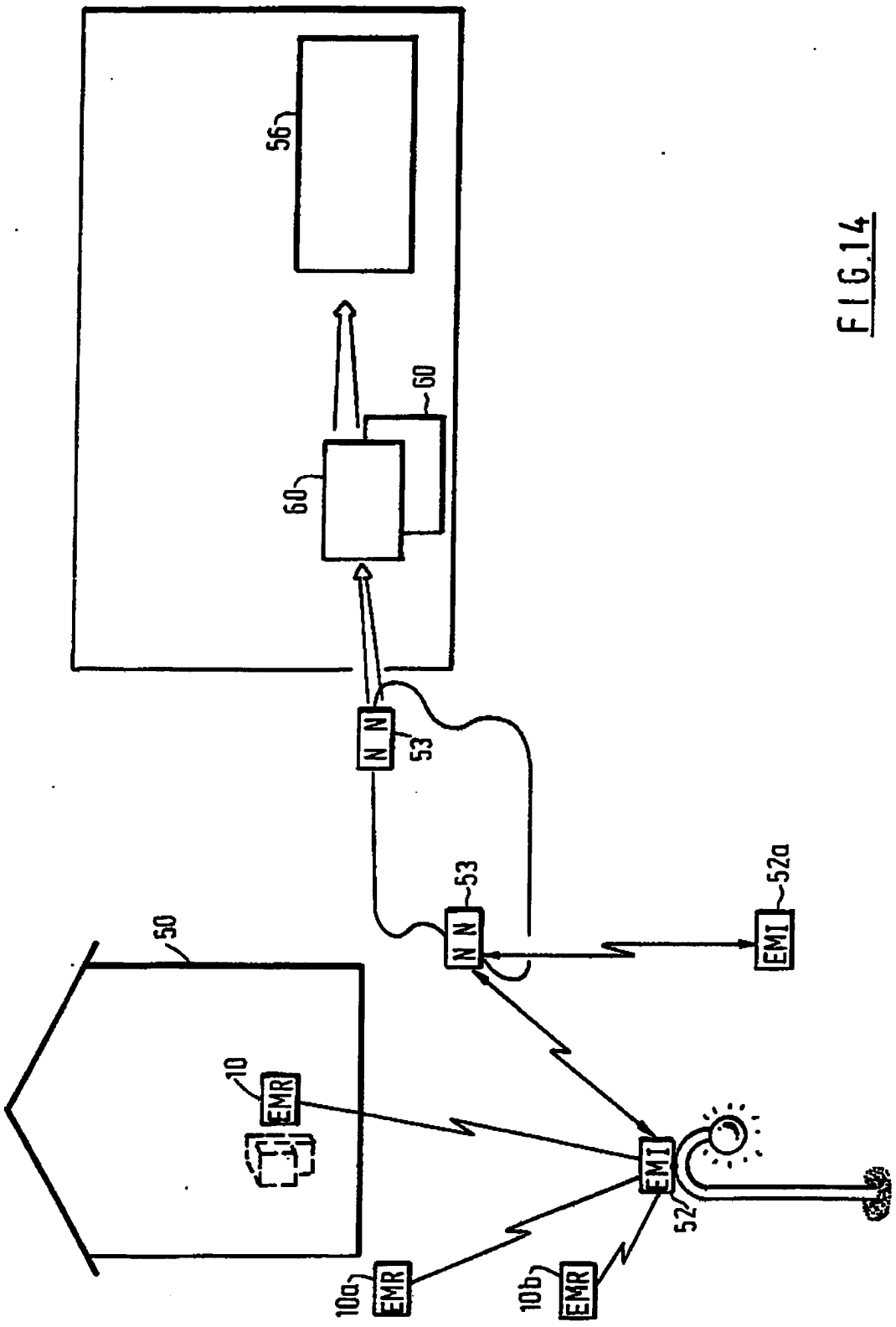

FIG.14

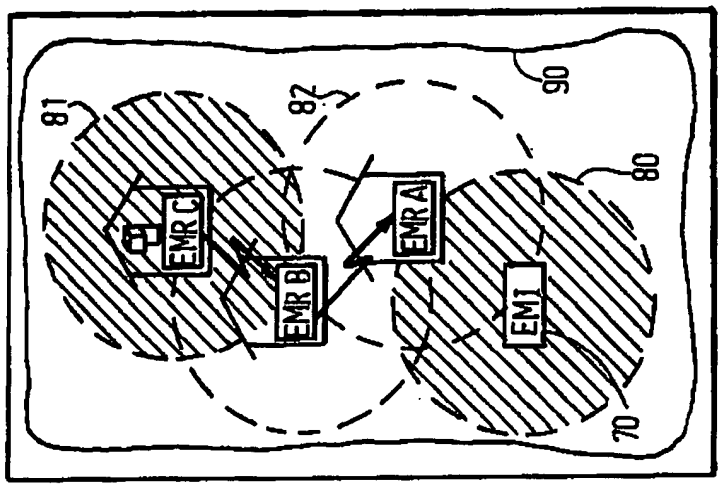

FIG.17

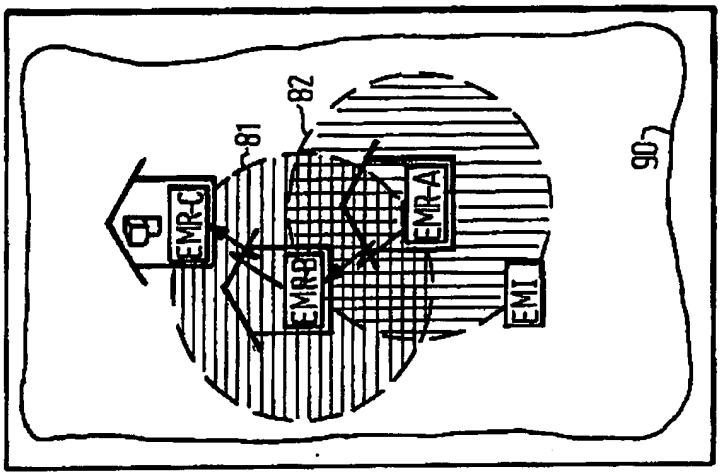

FIG.16

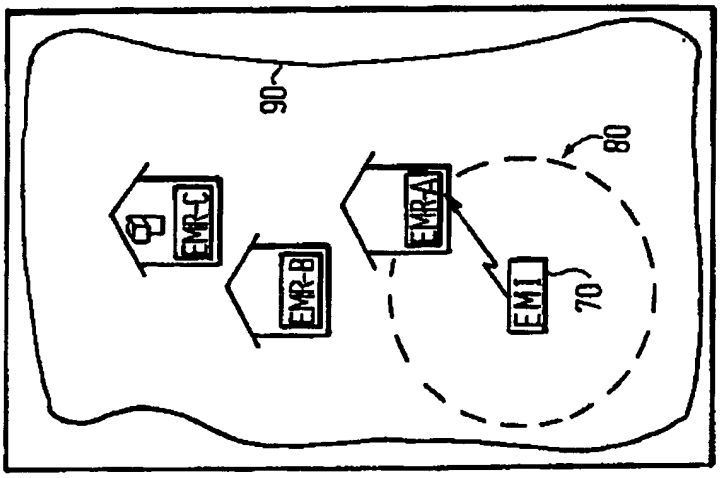

FIG.15

"IMPROVEMENTS IN OR RELATING TO METERS"

This invention relates to improvements in or relating to meters. In particular, it relates to meters of the type used to record the rate of consumption of electricity, gas, water, etc. (generally referred to as power) by customers of utility companies.

Meters are manufactured for a variety of end users in a variety of different embodiments. However, in general, these meters rely on the use of a disc which rotates in direct relationship relative to the quantity of power being recorded by the meter. For example, in the case of a meter of a type used to indicate the rate of consumption of electricity in a circuit, a disc rotates at a velocity proportional to the quantity of electricity passing through the meter.

The disc is mechanically connected via suitable gears, etc. to a set or sets of wheels a selection of which wheels each bears the number 0-9 around the periphery thereof. Usually, there are seven such wheels such that for every revolution of one of the wheels, an adjacent wheel rotates one tenth of a revolution. The relationship between the disc and the wheels is that for every say 500 revolutions of the disc, one unit or kilowatt hour (kWH) of electricity

has been used by the consumer. The meter is the foundation for enabling the utility company to bill the consumers.

In the case of Ireland, the Electricity Supply Board (ESB) is responsible for the supply of the nation's electricity needs. The ESB has approximately 1.1 million meters installed throughout the country. It is estimated that from 70-75% of these meters are located within the premises of the consumers which makes easy access for meter reading very difficult. Approximately 30% of consumers' bills are estimated by either the ESB, using their archival computer data information relating to that account, or by meter readings provided by the consumers. Ideally, each meter should be read at intervals of approximately two months.

Furthermore, due to the restricted access ESB personnel have to consumers' meters, it is estimated that between 1% and 3% of revenue is lost due to theft where consumers tamper or by-pass the meter.

The transfer of the information from the meter to a computer to enable a consumer's account to be prepared is a time consuming task. A representative of the company, known as a meter reader, is required to visit the premises of each consumer once every two months. If access is gained, the reading of the meter is written on an appropriate form which matches the meter reading with the account number of the consumer. This information is brought back to an office where it is transferred by manual means to the company's computer to enable the consumer's bill to be prepared.

The step of transferring the information from the meter to the computer, referred to as a reading cycle is a time consuming and expensive task. The following steps serve to illustrate the cycle.

1. Printout and distribute Walk-Orders to meter readers.

A Walk-Order is a written protocol which enables the meter reader to visit the premises of customers in a logical and time efficient fashion. Cognizance is also taken to ensure that the meter reader is aware of all the meters in particular premises.

2. Meter reader personnel (via Walk-Orders) trek to locate the meters.

..If the meter is found (accessed) the readings are transcribed and exceptional or suspect readings are reported.

2a ..If the meter cannot be accessed, an estimated reading is made and a card is left for the customer to perform the reading of the meter.

3. Once complete, the Walk-Order forms are optically read and the customer accounts are updated.

3a ..If an exceptional or suspect reading is reported then additional manual analysis and processing is required.

..Customer performed meter readings are also manually processed and the customer's account updated.

4. The billing cycle begins.

It is an object of the present invention to overcome these problems.

The invention, therefore, provides a meter apparatus of the type used to measure the usage by a consumer of electricity, gas, water or the like, hereinafter collectively referred to as power, which meter apparatus comprises a disc member rotatable at a velocity which is directly proportional to the rate or quantity of usage of the power; sensor means for detecting the velocity of rotation of the disc member, which sensor means is adapted for said detection in the absence of physical contact with the disc member; said sensor means being also adapted for outputting a signal in response to said rotation.

Preferably, the sensor means further comprises means for detecting the direction of rotation of the disc member.

Preferably, the sensor means comprises means for directing a beam of radiation onto one face of the disc member; and a radiation detector means; the disc member having means for selectively altering the direction of said beam relative to the detector means; said detector means being automatically responsive to the presence or absence of said radiation.

Preferably, the means for selectively altering the direction of said beam is located on an imaginary circular line on said face of the disc member, the centre of which line corresponds with the rotational axis of the disc member.

Preferably, the directing means and the detector means are located on the same side of the disc member; the disc member is adapted for reflecting said beam of radiation to the detector means and the direction altering means comprises a non-reflective portion of the disc member.

Preferably, the non-reflective portion of the disc member is located on said imaginary line.

Preferably, the directing means and the detector means are located on opposing sides of the disc member and the direction altering means comprises an opening in the disc member.

Preferably, said opening is located on said imaginary line.

Preferably, the disc member comprises at least two direction altering means for enabling the direction of rotation of the disc member to be detected.

Preferably, the beam of radiation is infra-red radiation.

Preferably, the output signal is stored in a non-volatile electronic device.

Preferably, the non-volatile electronic device is also capable of storing other information including an account number unique with respect to each meter apparatus.

Preferably, the meter apparatus further comprises tamper indicating means which, when actuated, transmits a signal for storage in the electronic device.

Preferably, means is provided for the wireless transmission of data from the electronic device to a receiver means.

Preferably, the electronic device further comprises means for receiving a wireless transmission from the receiver means.

Preferably, the receiver means is adapted for electronic storage of data from a plurality of said electronic devices.

Preferably, the receiver means is adapted for indirect wireless communication with a first electronic device via a direct wireless transmission through one or more other similar electronic devices.

The invention will be understood in greater detail from the following description of preferred embodiments thereof given by way of example only and with reference to the accompanying drawings in which:-

Figure 1 is a front view of a meter apparatus according to the invention;

Figure 2 is a side view of the meter apparatus of Figure 1 of the drawings;

Figure 3 is a perspective view of the meter apparatus of Figure 1 of the drawings;

Figure 4 is a plan view of some of the components of the meter apparatus of Figure 1 of the drawings;

Figure 5 is a side view of the device of Figure 4 of the drawings in one condition of use;

Figure 6 is a side view of the device of Figure 4 of the drawings in another condition of use;

Figure 7 is a plan view of a disc member and sensor means for use with the device in Figure 4 of the drawings;

Figure 8 is a side view of part of the sensor means of Figure 7 of the drawings;

Figure 9 is a schematic view of the electrical connections of the sensor means of Figure 7 of the drawings;

Figure 10 is a block diagram of a device for use with the meter apparatus of Figure 1 of the drawings;

Figure 11 identifies detectable states of movement of the disc member of Figure 7 and sensor means of Figure 7 of the drawings;

Figure 12 is a schematic view illustrating a first use of the meter apparatus of Figure 1 of the drawings;

Figure 13 is a schematic view illustrating a second use of the meter apparatus of Figure 1 of the drawings;

Figure 14 is a schematic view illustrating a third use of the meter apparatus of Figure 1 of the drawings; and

Figures 15-17 are schematic views illustrating a fourth use of the meter apparatus of Figure 1 of the drawings.

Referring now to the drawings and in particular to Figures 1-9 thereof, there is shown a meter apparatus 10 according to the invention which comprises a housing 11, a disc 12 coupled to and/or meshing with a plurality of wheels including digital wheels each of which carries on the periphery thereof a set of the numerals 0-9; and a sensor means 13. The housing 11 is essentially partitioned into three compartments 11a, 11b and 11c. The compartment 11a houses the disc 12 and associated wheels; the compartment 11b houses electrical connections through which electricity for consumption by a consumer's electrical system is wired; and the compartment 11c houses electronic equipment 14 which will be discussed later in the Specification. With the exception of the provision of a sensor means 13, the electronic equipment 14, tamper proof switch or sensor 15, and the cover for the electrical connections, the meter apparatus 10 is substantially the same as a conventional meter apparatus designed to indicate the amount of electricity consumed by a consumer's electrical system. The amount of electricity consumed is displayed on a mechanically operated digital readout, details of which are well known and need not be described here.

The disc 12 rotates at a velocity which is proportional to the rate of consumption of electricity. In the present example, the disc 12 will rotate 375

revolutions per kWH of electricity consumed. It will, of course, be appreciated that the number of revolutions per kWH can vary for different meter type constructions.

The front of the housing 11a is covered by a glass faced plate 16 supported by a removable support 41 of the housing 11a. Behind the plate 16 is a metal support plate 16a having a slot (not shown) therein through which one digit of each digital wheel may be observed. The disc 12 has an axle 17 which rotates in response to the rate of consumption of electricity. The axle 17 is essentially parallel to the plates 16, 16a with the disc 12 in perpendicular relationship thereto. The axle 17 has a worm wheel 18 in meshing engagement with one wheel 19 which in turn is in meshing engagement with a first of said digital wheels which first digital wheel rotates one revolution for each kWH of electricity consumed. The remaining digital wheels are in engagement with the first digital wheel in a known manner so as to rotate in turn one revolution for every ten revolutions of the immediately adjacent digital wheel.

Mounted on the plate 16a is the sensor means 13. The sensor means 13 comprises at least one sensor 21 comprising a GaAs infra-red emitting diode 23 and associated npn silicon phototransistor 24 mounted in side-by-side relationship on parallel axes. In the present example, there is an additional sensor 22 similar to the sensor 21 mounted on the plate 16a.

The sensors 21, 22 are mounted so that the sensor 21 is located above the disc 12 and adapted for tracking an imaginary line 30 on the face of the disc 12. The sensor 22 is similarly located but positioned ap-

proximately 5mm away from the sensor 21. The diameter of the disc 12 is approximately 90mm; and the diameter of line 30 is approximately 70mm.

The face of the disc 12 has a reflective characteristic and with the sensors 21, 22 located an appropriate distance above the disc 12, infra-red radiation transmitted from the diode 23 of each sensor 20, 21 is reflected by the disc 12 to the respective phototransistors 24 of each sensor 21, 22.

On the line 30 is placed or painted a black non-reflecting surface 31. When the surface 31 is below the sensors 21, 22, infra-red radiation is not reflected. The sensors 21, 22 are of a type which output a signal only when infra-red radiation is detected by phototransistors 24. Accordingly, during the period when the surface 31 is below the sensors 21, 22 no output signal will be present. The presence or absence of these signals can be monitored via cables 25, 26 (Figure 9).

The use of two sensors 21, 22 (also referred to as "A" and "B" respectively) enables the direction of rotation of the disc 12 to be monitored. As the disc 12 rotates anticlockwise, it will be appreciated that the sensor 22 will detect the surface 31 earlier than the sensor 21. By connecting the cables 25, 26 to the electronic equipment 14 which comprises, inter alia, a non-volatile RAM memory 40, the absence of a signal first in cable 25 and then in cable 26 will indicate that the disc 12 is rotating anti-clockwise. If a reverse signal sequence is detected, it would mean that the disc 12 was rotating clockwise. A clockwise rotation disc 12 would indicate that a consumer has

placed a device (not shown) near or on the meter apparatus 10 in an attempt to avoid payment for electricity consumed.

In Figure 11 of the drawings, there is shown the various detectable states of the disc member 12 relative to the sensor means 21, 22 (A,B). In Figure 11 the sensors 21, 22 (A,B) are shown at a 12 o'clock position. The normal direction of rotation of the disc 12 is anti-clockwise (i.e. in the direction of the arrow 70). The abnormal direction of rotation of the disc 12 is clockwise (i.e. in the direction of the arrow 71). For reasons of clarity, the surface 31 is shown without shading. As the disc 12 rotates anti-clockwise, the sequence of events can be followed by reference to the arrows 72. The sensors 21, 22 (A,B) do not detect any surface 31; then the sensor 22 (B) detects the surface 31; next, both sensors 22, 21 (B,A) detect the surface 31; the sensor 21 (A) only detects the surface 31; and finally neither sensor 21, 22 (A,B) detects the surface 31. In the normal sequence shown below, A or B imply that the respective sensor 21, 22 has detected the surface 31. An abnormal or reverse sequence is also shown below.

	Abnormal (reverse) sequence	Normal sequence
	A | B	A | B
1)	A | B	A | B
2)	A | B	A | B
3)	A | B	A | B
4)	A | B	A | B
5)	A | B	A | B

It will be further appreciated the direction of rotation of the disc 12 could also be determined by using one sensor 21 and two discrete black surfaces 31 and 32 the latter shown in dotted outline in Figure 7 of the drawings.

For a disc 12 capable of rotating at 37 revolutions/kWH, then for a consumption of 60 amp (max) there will be 1.375 revolutions per second or 727ms/rev. With a gap of 5mm between the sensors, the time which elapses between the sensor 22 detecting the black surface 31 and the sensor 22 detecting the same surface 31 will be about 16.7ms.

In the case of a disc 12 which rotates at 187.5 revs/kWH, then for a consumption of 80 amps (max) there will be 0.917 revolutions per second or 1.1 seconds per revolution giving an elapsed time of about 25.3 ms.

Cables 27, 28 provide a controlled +5 or 0 volt power for the emitters 23, the sensors 24, and the tamper-switch 40. Resistors R3 and R4 provide a pull-up for the reflective opto switches 22 and 21 respectively.

Referring to Figure 6, the tamper-detect switch 15 is provided and located in the housing 11a so that if the support 41 for the plate 16a is removed, the absence of a signal caused by the opening of the switch 40 (Figure 9) will cause the condition to be stored in memory via on cable 29. Resistor R1 provides a pull-up (to +5) when switch 40 is normally open in the 'non-tamper' position.

The validity of signalling on cables 25, 26 and 29 depends on the state of control imposed on cable 27. This signal, referred to as "Emitter Control" is switched active (+5) prior to monitoring the signal states of cables 25, 26 and 29. Switched control of cable 27 is conducted under micro-controller control 43 (Figure 10) and improves power consumption efficiency, as well as providing a mechanism for determining the integrity of the tamper switch 15 and opto-sensing devices 21 and 22. Signal states are read by micro-controller 43 and retained in memory 40.

The cable assembly 29a may be passed through a hole (not shown) in the wall which separates the housing 11a from housing 11c.

To accommodate the electronic equipment 14, the standard sized terminal cover of a conventional meter apparatus is replaced by one incorporating the housing 11c. Accordingly, the area of footprint of the meter apparatus 10 will be identical with the footprint area of a conventional meter apparatus of the same type.

The meter apparatus 10 according to the invention can thus function in a manner similar to a conventional meter apparatus by displaying on the digital wheels the quantity of electricity. However, in addition, the meter apparatus 10 has the capability of storing in the memory 40 information relating to the number of revolutions of the disc 12, the direction of rotation of the disc 12 and whether the anti-tamper switch 15 has been actuated.

In addition to the memory 40, the electronic apparatus 14 also comprises an intermodular interface 41, a transceiver 42, a microcontroller 43, a power supply 44, a back-up power supply 44a; a real time clock (RTC) 45, an aerial 46 for the transceiver; a sensor interface module 47; and an external applications adaptor 48.

The intermodular interface 41 provides an electronic access point for signalling from the sensors 15, 21, 22 and others (not shown). In addition, the intermodular interface 41 provides output latch states to the emitter devices 23 and the various signal voltage pull-up resistors R1 through R4 on Figure 9 and other devices (not shown). The intermodular interface 41 can be of a well known type of digital receiver or gate for input sensors or conventional digital data latches for output signalling and control. Preferably, the intermodular interface 41 can be implemented by using the standard Input/Output Port interface of the microcontroller 43.

The transceiver 42, which comprises a radio receiver 42a and a radio transmitter 42b enables radio communication to take place via the aerial 46 between the meter apparatus 10 and an electronic meter interrogator (EMI) which will be discussed later in the Specification. The transceiver 42 is implemented on a narrow bandwidth utilising a simpex radio frequency channel (single frequency). The simpex channel can exist in the radio spectrum from 150 kilohertz to well into the UHF region (gigahertz range). Standard pulse-code or pulse-width modulation techniques, via keyed continuous wave (type A1) transmission, are preferred. In its simplest form, the transceiver 42 can

consist of a stabilised oscillator which can function as a keyed oscillator for transmitting, or a regenerative/ super-regenerative detector for receiving. An audio amplifier/conditioner will also be employed for receiving.

The microcontroller 43 serves to electronically control the activities of the memory 40, the intermodular interface 41, the transceiver 42; the real time clock 45; the sensor interface module 47; and the external applications adaptor 48. The microcontroller 43 can be a standard type such as the Intel 8000 series microcontrollers (8031, 8039, 8048, 8051, etc.).

The power supply 44 derives power for the mains electricity supply feeding the meter. The function of the power supply 44 is to supply the required current and voltage needs to operate other components of the electronic apparatus 14 and sensor means 13. The power supply 44 is of the well known A.C. to D.C. variety and may or may not utilize a transformer (transformerless). The back-up power supply 44a essentially comprises a rechargeable battery (not shown) and related circuitry of a well-known type which supplies power in the absence of the power supply 44. No further description of the power supply 44 or back-up power supply 44a is deemed necessary on the present Specification.

The RTC 45 comprises of a device for maintaining a 24 hour day clock and calendar. The basic periodic timing reference for the RTC is derived from either a crystal oscillator or from the mains 50 hertz A.C. A basic timing reference interval of one second or less is preferred. The RTC 45 can consist of any variety of standard off-the-shelf RTC integrated circuits, or simply monitoring the basic timing

reference and maintaining the RTC 45 under software means via the microcontroller 43.

The use of the RTC 45 enables the storage in the memory 40 of the quantity of electricity consumed having regard to the time during which the consumption took place. This is particularly useful for use in situations where, for example, electricity consumed before the hours of 2300h and 0800h are at a rate per kWH which is less than for electricity consumed during the period 0800h to 2300h.

The sensor interface module 47 provides a interface between the sensors 15, 21, 22 and the intermodular interface 41. In addition, the module 47 receives a clock reference signal via the cable 60. Furthermore, the module 47 is connected to a service mode switch (not shown) via the cable 61.

The external applications adaptor 48 enables the detection of events other than events associated with the meter apparatus 10. These events include, for example, water metering monitoring, gas meter monitoring, etc.

The electronic equipment 14 together with the sensors 21, 22 is hereinafter referred to as an electronic meter reader 100 (EMR). The EMR may be used in conjunction with a meter management system (MMS).

The MMS is a hierarchial system which consists of up to four main networking components. The objective of the system is to provide a pathway for the automatic electronic transfer of electricity consumption readings (as monitored at the meter apparatus 10) to the utility company's user billing/accounts system. The

information is in computer readable form and requires no manual (human) intervention.

The target MMS topology, and the devices involved, is shown below.

The application end-users consist of the 'BILLING/ACCOUNTING SYSTEM' (at top) and a plurality of meter apparatus 10 (at the bottom). The four components of the Meter_Management_System are included in a layered topology. In priority of overall control the devices are:

1) MMS DELIVERY SYSTEM
-this system is the MMS interface into the BILLING/ACCOUNTING SYSTEM. Its primary functions include:
...general management and control of the MMS domain. (includes fault isolation and maintenance of MMS network)
...performing electronic retrieval of Meter-Readings for the MMS domain. This may be either online (via NN devices) or offline (via a human meter reader PC device). ...delivery of metering data to BILLING/ACCOUNTING SYSTEM in computer readable form.

2) NN (Network Node)
-this layer in the hierarchy provides the link for fully automating and monitoring the Meter Management System. Initial phases of the MMS do not include automated NN layer.

PC (Personal Computer) under Meter-Reader Control
-this device emulates an offline NN layer. The realtime data layer between the EMI and MMS Delivery System does not exist with this data retrieval mechanism. Data collected/retrieved must be manually transfered from PC-to-MMS Delivery System.

NOTE: the NN/PC layer is classified as a transport and requires virtually no data-store capability or data-management functionality.

3) EMI (Electronic Meter Interrogator)
-this device is the heart of data retrieval for the MMS. In addition performing data collection and store functions, this layer is responsible for managing the bulk of wireless communication activity and meter security monitoring. Based on geographical constraints, this device is able to handle/control meter data retrieval and store for from 1 to 4000 EMR's (meters).

4) EMR (Electronic Meter Reader)
-One EMR is required for each electrical circuit. The EMR, as indicated earlier, is capable of:-
...power consumption tracking and reporting
...rates handling (as dictated by the parent EMI)
...Tamper detection and reporting.

The simplest MMS topology consist of an EMI controlling a domain of multiple EMR devices. The simplest scenario for allowing a human user access to the MMS is via a PC connected to the EMI as a psuedo NN device.

The interface operations required to support the main Meter Management System is summarized below. Two categories of interfacing are identified. Both pertain to the EMI layer, the interface the NN (higher) layer, and the interface to the EMR's (lower layer).

Control and command requests are always directed by a higher level in the MMS hierarchy. This is to say that the EMI devices are controlled by the

NN layer (and above), while the EMI layer controls the EMR Layer (lower layer).

Two main functions are involved in the information retrieval process. They are:

... Data collection (incorporates EMI and EMRs).
... Data transfer (incorporates DS, NN, and EMI components).

The EMI device is the architectural interface between the collection and transfer operations. It maintains an active state of data collection and store, while passively monitoring for requests from the higher NN component for initiating data transfer.

Installing and/or configuring the electronic personality of the EMR device, with respect to a specific meter and customer account, is performed via wireless interactions between the EMR device and the Installer's EMI device. Configuration information includes:

...METER NUMBER and TYPE (stamped on meter's face plate)
...GENERAL KWH Reading as registered on the meter's face.
...MMS NETWORK DOMAIN and EMR IDENTIFIERS
...CUSTOMER ACCOUNT NUMBER
...CUSTOMER NAME and STREET ADDRESS
...TARIFF RATE CODE for customer
...DATE and TIME

Once configured, verified and sealed, the installer must us the EMI device to purge security violation indications (which will always occur during an EMR hardware installation). To complete the electronic

installation, the installer should also retrieve and report the current EMR information listed below:

... TAMPER count
... CONFIGURATION_CHANGE count
... POWERFAULT count
... DOUBLE_TARIFF_RESET counts

...current meter KWH reading

The four major features provided by the EMR device are:

...Tracking KWH Power Consumption (electronic tracking and translation of the single tariff KWH counting function).

...Tamper Detection and Meter Security Assurance

...Double Tariff Handling (Day and Night Rate emulation using a single tariff meter)

...Remote 'ANY-TIME' Accessability to all metering information via wireless

The EMR device transforms the mechanical operation of the meter into an electronic form. The characteristics of the single tariff meter are maintained electronically. The primary benefit obtained by incorporating the EMR device is the ability to gain easy 'any time' access to metering information independent of the meter's location (in or out of doors). The meter always retains and maintains its mechanical operating identity and the normal metering information that is available on it's face.

One important feature provided by the EMR device is the ability to maintain continual electronic surveillance of the meters physical security.

Electronic surveillance consists of detecting and indicating security violations. Wireless queries of the EMR using an EMI device will retrieve tamper indications that have occurred. A tamper indication remains active within the EMR device until it is purged by an authorized EMI user. Once purged, the tamper indication is counted and the count recorded within the EMR device. This count cannot be altered by any external means. Tamper counts may be read by authenticated EMI users and validated against previously read counts to assure the integrity of the tamper detection system.

The tamper proof switch or switches 15 are in the normally closed position when the cover or covers of the housing 11 are properly installed. The removal or attempted removal of a cover will cause a tamper violation to be electronically indicated. Detection of a tamper violation does not cause a visual signal or audible alert to be sounded. The indication is electronically retained for later reporting and purging via an EMI device as previously mentioned.

The EMR device is also equipped with a mechanism to assure that the disc 12 is revolving properly. Daily statistics are maintained that reflect the lack of meter wheel movement for consecutive 24 hour periods. This information is used to identify trends indicating the absence of rotation of the disc 12 which could be caused by the more devious power theft. The EMR device may be equipped with a small resistive load (not shown) that can be switched on automatically for

testing the rotation of the disc 12. In the absence of movement of the disc 12 for an extended period of time this test will verify that the disc 12 is functioning properly.

Although electronic emulation of the single tariff meter is always performed by the EMR device, double "economy" tariff functionality is also provided. The EMR registers the power consumed both during the daytime and the night-time. Double tariffing at the EMR device is a value added enhancement of the single tariff meter.

From signals derived from the EMI device, the RTC 45 within all EMR devices can be set or changed. Selecting other non-standard day and night rate periods is also possible.

The following information is maintained for double tariff handling:

... Daytime Register (registers kWHs used during the daytime)

... Night-time Register (registers kWHs used during the night-time)

... Register Reset Counter (increments each time the day and night registers are purged by an authenticated EMI device user)

The daytime and night-time register counts reflect the accumulated kWH count since last purged. Once purged, the day and night registers are reset to zero and the "register reset counter" is incremented.

The ability to provide wireless two way communication between the EMI and the EMR device is of primary importance. No longer is the retrieval of metering information dependent upon physically locating and viewing the face of the meter apparatus 10 installed indoors (within the confines of the customer's premises); the meter apparatus 10 are now electronically exposed. The requirement for customer presence and/or assistance in reading the meter apparatus 10 can be eliminated. Remote electronic retrieval of metering information is assured at anytime.

A communicator can participate in two way communication for distances of over 100 metres. Further distances can be attained by utilising intermediate EMR device communicators as communication relays (refer to Figure 13). This is also referred to as "meter-stringing". Intermediate EMR devices serve for sole purpose of communications link between the EMI device and the target EMR at the end of the communication link.

Two basic types of EMR devices exist. They are referred to as a "type A-EMR" or "type B-EMR". While the functionality of both EMR types is essentially the same, the type B-EMR has a more powerful communicator capable of communication up to a distance of 1000 metres. The type-B communicators are strategically placed within an EMI's wireless visibility to increase communication reliability and information access integrity. Geographical, industrial interference, and a multitude of environmental conditions dictate the need for type B-EMRs. All EMR communications share a single wireless channel with all other EMR device and an EMI device in the vicinity.

EMR devices receive requests and commands from a single EMI source as defined within the MMS architecture. The ability of an EMR device to relay a request that is targeted to another EMR device is defined.

Authorized personnel can selectively query the desired EMR device. A communicator within the EMR device is continually monitoring the wireless communication channel, awaiting selection. Once selected, the EMR device will return an immediate wireless response in reply to the EMI query. This response contains the information requested by the EMI device. The EMR device will remain silent until queried again.

Three types of communications identifiers are available for selecting the desired EMR device. These identifiers are set when the electronic personality of the EMR device is configured. They are:

Customer account number;
Meter number identifier; and
A Meter Monitoring System communications Network Identifier

Using the customer account number would be the most practical way for the meter reader to identify the meter. When the meter reader is in the vicinity of the desired meter the customer account number is entered into the EMI device and a wireless query initiated. The requested information is immediately returned by the selected EMR device and displayed for viewing by the meter reader. A "reader-to-meter" distance of 100 meters or more is possible. This distance limit has

little significance in view of the current meter reading practices and procedures. It is significant, however when further automation of the meter reading process is required.

In the event that normal communication identifiers are not known to meter-reading and/or service personnel, the identifiers can gain electronic access to the "customer account" number by using the meter number as the communication identifier. It is assumed that the meter-reader/service personnel have acquired this meter number by seeking, finding, and reading the number from the face of the meter apparatus 10. Close range wireless communication, when using the meter number identifier, is recommended to prevent any possible contention with other meters with the a similar digit number. Once the customer account number has been acquired electronically, normal electronic meter reading procedures can be conducted.

Wireless communication "network identifiers" are assigned to all Meter Monitor System communicating entities (e.g. EMRs, EMIs, etc.). Network identifiers provide the foundation for further automation of the meter monitoring process. They also provide additional wireless communications security.

The wireless network identification concept divides geographical regions into cells or "domains". Several thousand EMRs can be located within a single domain. Domains can coincide with rural areas that may be void of meters and hence, have no network identifiers assigned. A network identifier assigned to an EMR device includes both "domain and EMR" identification. Figures 12-14 provide a simple illustration of "domains" as defined by the MMS network architecture.

In Figure 12 of the drawings, there is shown schematically how an EMR device and an EMI device may be incorporated into a method for a relatively simple semi-automated meter reading/customer billing system.

A customer's property 50 having the apparatus 10 (EMR) according to the invention installed therein is shown. A meter reader using an EMI device 51 interrogates the EMR via wireless communication and receives the relevant information pertaining to that EMR including account number, etc. Having carried out this operation in relation to several EMR's (typically say 500), the information in the EMI device 51 is downloaded to a delivery system 55 for subsequent transfer to the company's computer system 56 where the customer's account is prepared. As indicated earlier, the most significant advantage of this method is that under normal circumstances, no access to the customer's property 50 is required.

An enhancement of this method is shown in Figure 13 of the drawings where an EMI device 52 is installed on a pole 70 (typically an electric light support pole). The EMI device 52 can, via wireless communication, interrogate a plurality of EMI devices 10, 10a, 10b, etc. on a command from the EMI device 51 or at any time if desired. The EMI device 51 can, where appropriate, interrogate the EMI device 52 and download, via wireless communication, all the information in the EMI device 52. As in Figure 13 of the drawings, the information in the EMI device 51 is then transferred to the delivery system 55. Figure 13, therefore, schematically illustrates the setting up of a cell or domain structure and permits a much more rapid

information gathering system and compared with the method illustrated in Figure 12 of the drawings.

A still further enhancement of the method is illustrated in Figure 14 of the drawings where a fully automated system is illustrated.

The components of Figure 14 of the drawings are identical to the components of Figure 13 of the drawings except that it is now no longer necessary for a meter reader, in the human sense, to be employed. Instead, a network comprising a plurality of network nodes 53 is set up. The various EMI devices 52, 52a, etc. transmit their information via the network nodes directly to the delivery system 55 under the overall control of the meter management system (MMS) 60.

The ability of an EMI device to access metering information is enhanced by the use of EMR communication relays. Using MMS "network identifiers", multiple EMR device communicators may be included in the communication relay link between the EMI device and the target EMR.

The EMR device is also provided with the ability to receive and record the network identifiers of nearby EMR devices that are also communicating with the EMI device. These identifiers can then be retrieved and used by MMS network personnel to analyze the wireless visibility of each and every EMR device. Using this information, effective and efficient communication relay strings can be determined and defined between the EMI device and a target EMR.

MMS network monitoring personnel may retrieve "wireless visibility" information for each EMR device in a domain. This information can then be used for determining efficient EMR relay strings. In the example shown in Figures 15-17 of the drawings, there is shown an EMI device 70 interrogating an EMR-A in a customer's property. The limit of wireless communication is shown by the dotted line 80. Accordingly, the EMI device is unable to directly communicate with the EMR-B or EMR-C in the domain 90. The transceiver 42 of each EMR-A, EMR-B, EMR-C, etc. device is equipped with facilities for enabling it to function as a wireless relay. Accordingly, with the target EMR-C device within wireless visibility of the EMR-B device (denoted by the line 81) and the EMR-B device in wireless visibility of EMR-A device (denoted by the line 82), the EMI device can communicate with the EMR-C device via the EMR-A device and the EMR-B device. It will be appreciated that the limit of intermediate EMR devices (in this case EMR-A and EMR-B) is not limited in number.

The following "visibility" information would result form interrogating the EMR devices:

EMR	Wireless Visibility
EMR-A	to EMR-B and the EMI
EMR-B	to EMR-A and EMR-C
EMR-C	to EMR-B only

The EMR device maintains a valuable data base of metering information. This information includes the EMR's "electronic personality" that is configured to match the power meter specification and general metering

environment. The device also retains information counts and registrations that are collected during the EMR's meter monitoring process.

The meter's "electronic personality" is set up during the installation of the EMR device. Configuring the EMR device is performed using wireless interactions between the EMR device and an EMI device. This configuration information is categorized into two areas, they are:

... Meter Specification
... Customer-Account

The personality of the EMR device can include the following data: Meter Specification

-METER_NUMBER	...meter's meter-number
-METER_TYPE	...meter type
-METER'S_KWH_REGISTRATION	...as per meter's face reading
-METER'S_PARTIAL_KWH-VALUE	...hundreths of a kWH reading
-METER_WHEEL'S_REVOLUTIONS/KWH	...number of revolutions of the meter wheel for each kWH registration.
-EMI_WIRELESS_IDENTIFIER	...EMI (domain) identifier that the EMR is authorized to communicate with.
-EMR_WIRELESS_IDENTIFIER	...identifier used to select and interact with the EMR.

Customer-Account

-CUSTOMER_ACCOUNT_NUMBER ...customer account no.
-CUSTOMER_NAME ...customer's name
-CUSTOMER_STREET_ADDRESS ...customers street address
-RATE_CODE ...General or Economy or a business rate code.
-TIME ...current time of day

Once configured, the EMR device continually monitors the metering environment and retains valuable metering information. This information is accessible "any-time" via wireless requests initiated by a nearby EMI device.

The information that is monitored and saved includes security related data, various registrations, and general statistics. The following data is included in the information saved:

Security related data

-CONFIG_CHANGE_COUNT ...count of configuration change sessions that have occurred for the EMR device.
-TAMPER_VIOLATION_COUNT...current count of tamper violation conditions that have been detected by the EMR device.
-POWER_FAULT_COUNT ...on going count of power faults that have occurred at the EMR device.
-DT_RESET_COUNT ...current Double-Tariff reset count
-(Tamper, power-fault, and config-change indicators) ... These indicators identify a recent or new change of state.

Registrations

-GENERAL_KWH_REGISTER ...electronic KWH reading that is also displayed on the face of the single tariff meter.

-ECONOMY_DAY_REGISTER ...accumulated day registration since last read.

-ECONOMY_NIGHT_REGISTER...accumulated night registration since last read.

Statistics

-(miscellaneous communications channel state and integrity counts) ...information that can be used to monitor the integrity of the MMS communication channel and its quality.

-(MMS network identifiers of other EMR devices that are are visible, via wireless, to this EMR) ...identifiers of EMR devices that have been detected communicating with the EMI device.

-('no meter wheel revolution' statistics) ...daily tracking of 'no movement of the meter wheel'. Maintains daily statistics since last meter-reading.

The EMI device is the sole means of electronic access to information held by EMRs. The EMI device is portable and can be easily carried by meter_reader/service personnel.

The EMI device may be either (a) a Meter-Reader EMI, or (b) a Service EMI.

The portable Meter-Reader EMI device caters to the functions that pertain to electronically

receiving information from the EMR via wireless communication and is classified as a retrieve only device. At a minimum it can serve as simply an electronic access device. In this scenario, the meter reader manually transcribes electronic information retrieved reading onto the hardcopy "walk-order" form(s) in which he/she is familiar. The Meter-Reader EMI device can also provide data access, store, and forward capability. Information retrieved by using the EMI device is stored, in non-volatile form, for forwarding to the customer accounting system when the reading cycle is completed.

The EMI is used to direct the meter reading process. The readings, retrieved via wireless from the EMR devices are saved in 'Electronic Meter Readings' area. In addition, the meter reading process will cause two data logging areas to be generated in the event that a tamper-violation-condition is reported, or if no-wireless-access can be achieved for a metering device. These logging areas are the 'tamper-violation log' and the 'No-Access log' respectively.

An electronic Walk-Order provides an electronic replacement to the hardcopy Walk-Order forms normally used by the meter reader. This allows for simple EMI keyins to manipulate the meter reading process. Each electronic Walk-Order entry includes the following data:

-CUSTOMER_ACCOUNT_NUMBER
-CUSTOMER_STREET_ADDRESS (optional)
-RATE_CODE
-enhanced meter (if an EMR device is installed)

The information received by the meter reader EMI from an EMR includes:

-GENERAL_KWH_REGISTRATION
-ECONOMY_DAY_REGISTRATION
-ECONOMY_NIGHT_REGISTRATION
-SECURITY/INTEGRITY_COUNTS to include config-change-count, tamper-violation-count, power-fault-count; no access count and DT-reset-count.

The config-change-count provides a mean of validating the integrity of the electronic information unique to an EMR device as well as the information that it is tracking. Each EMR device manages its own config-change-count. This count is incremented any time a change to the electronic configuration information takes place (i.e. meter number, account number, meter type, meter reading value, etc.) This count may be retrieved by an authorised EMI device and compared with previous readings for configuration integrity assurance. No provision exists for modification by this count by any outside source, authorised or otherwise.

The tamper violation count provides a log of CUSTOMER_ACCOUNT_NUMBERS which indicate a tamper-violation has occurred. A manual inspection of the metering environment and/or service of the meter apparatus 10 associated with the account should be performed.

The power-fault-count provides a count of the number of times that an EMR has detected the loss of mains power at the meter apparatus 10. The loss of mains power would typically be observed due to an interruption to electrical service due to damage by weather or a scheduled power outage conducted by the

power company. Collectively, power-fault-count information from a multitude of EMR devices could be used to identify, in detail, the extent of an unpredicted power outage. This information could be used for statistics purposes. More importantly, isolated instances of the power-fault-count of single EMR device could indicate abnormal power outage could result in an alternative tamper mechanism outside the scope of the meter enclosure environment.

The no access log data area provides a log of customer account numbers that were unable to access via wireless. This implies that the EMR device has failed or has been damaged (either maliciously or otherwise). A manual inspection of the metering environment and/or service of the meter associated with the account should be performed.

The DT-reset count provides a simulated means of duplicating the DT-reset mechanism of convention dual-tariff meters. The practices and procedures regarding DT-reset are standard and no further description is deemed necessary.

In addition to gathering basic meter reading information, the meter reading scenario can be expanded to retrieve security related information which can be used to verify the general integrity of the electronic metering process. Wireless interactions between the EMI and the target EMR device can include the transactions that follow:

Wireless Interactions

EMI Device request	EMR device response	Transaction
READ_METER VIA_ACCOUNT_NO ----->		...BASIC READING EMI device retrieves the meter's KWH
	<-----METER_READINGS	registration, day and night registrations and security indicators.
PURGE_DT_REGISTERS--->		...DT REGISTER RESET EMR device requested
	<-----PURGE_COMPLETE	to reset the DT day and night registrators to zero.(DT_RESET_COUNT is also incremented).
READ_INTEGRITY-------> COUNTS	<---INTEGRITY_COUNTS	..INTEGRITY VALIDATION EMR device reports the current config-change, tamper, power-fault, and DT-reset counts. These can be checked with previous readings.

In addition to simply retrieving meter readings, the Service EMI device is capable of configuring and modifying the complete electronic personality of EMR devices.

Servicing the EMR device is normally performed while at the installed meter's location. During initial EMR installation, the electronic configuration peculiar to the meter apparatus 10 (referred to as the meter's personality) must be performed. This requires that the meter's terminal cover be removed. Located in the area under the terminal cover (not shown) is the service mode switch. (Note too that removing the terminal cover will also result in a tamper condition to be registered. Co-ordination between servicing and completion of the service order must be carried out to distinguish this tamper condition from malicious tamper attempts.

The service mode switch must be set to "service mode" when configuring or altering the electronic 'meter specification' data and will cause the 'config-change-count' to be updated as configuration changes are specified.

Customer account information (i.e. account number, customer name and address) may be configured without the EMR device being in "service mode". When customer accounting information requires modification at the EMR device, it can be performed via remote wireless access to the meter while the EMR in either in or out of "service mode" and will cause the "config-change-count" to be altered.

In the event that a meter security-violation is reported, or the EMI user is unable to electronically access an EMR device, a manual investigation and/or service of the meter/EMR device is required. The service personnel, using the 'Service' EMI, are capable of retrieving valuable information that pertain to the security of the metering environment as well as general operating conditions. All EMR 'electronic personality' and metering information discussed above can be retrieved, via wireless, by the 'Service' EMI.

In addition, the wireless access of 'the change-of-state of EMR sensors' can be monitored and tracked on a real time basis. This allows service personnel to actually monitor the current state of tamper switches (either open or closed) at any time. It is also possible to track each revolution of the disc 12 as they occur. This facility permits enhanced surveillance of the actual operation at the meter apparatus 10 and can be used to identify unauthorized or theft of electric power.

This invention is not limited by the specific embodiment described which can undergo considerable variation without departing from the scope of the invention.

CLAIMS

1. A meter apparatus of the type used to measure the usage by a consumer of electricity, gas, water or the like, hereinafter collectively referred to as power, which meter apparatus comprises a disc member rotatable at a velocity which is directly proportional to the rate or quantity of usage of the power; sensor means for detecting the velocity of rotation of the disc member, which sensor means is adapted for said detection in the absence of physical contact with the disc member; said sensor means being also adapted for outputting a signal in response to said rotation.

2. A meter apparatus as claimed in claim 1 wherein the sensor means further comprises means for detecting the direction of rotation of the disc member.

3. A meter apparatus as claimed in claim 1 or claim 2 wherein the sensor means comprises means for directing a beam of radiation onto one face of the disc member; and a radiation detector means; the disc member having means for selectively altering the direction of said beam relative to the detector means; said detector means being automatically responsive to the presence or absence of said radiation.

4. A meter apparatus as claimed in claim 3 wherein the means for selectively altering the direction of said beam is located on an imaginary circular line on said face of the disc member, the centre of which line corresponds with the rotational axis of the disc member.

5. A meter apparatus as claimed in claim 3 or claim 4 wherein the directing means and the detector means are located on the same side of the disc member; the disc member is adapted for reflecting said beam of radiation to the detector means and the direction altering means comprises a non-reflective portion of the disc member.

6. A meter apparatus as claimed in claim 5 wherein the non-reflective portion of the disc member is located on said imaginary line.

7. A meter apparatus as claimed in any of claims 3-6 wherein the directing means and the detector means are located on opposing sides of the disc member and the direction altering means comprises an opening in the disc member.

8. A meter apparatus as claimed in claim 7 wherein said opening is located on an imaginary circular line on said face of the disc member, the centre of which line corresponds with the rotational axis of the disc member.

9. A meter apparatus as claimed in any of claims 1-8 wherein the disc member comprises at least two direction altering means for enabling the direction of rotation of the disc member to be detected.

10. A meter apparatus as claimed in any of claims 1-9 wherein the beam of radiation is infra-red radiation.

11. A meter apparatus as claimed in any of claims 1-10 wherein the output signal is stored in a non-volatile electronic device.

12. A meter apparatus as claimed in claim 11 wherein the non-volatile electronic device is also capable of storing other information including an account number unique with respect to each meter apparatus.

13. A meter apparatus as claimed in any of claims 1-12 wherein the meter apparatus further comprises tamper indicating means which, when actuated, transmits a signal for storage in the electronic device.

14. A meter apparatus as claimed in claim 13 wherein means is provided for the wireless transmission of data from the electronic device to a receiver means.

15. A meter apparatus as claimed in claim 14 wherein the electronic device further comprises means for receiving a wireless transmission from the receiver means.

16. A meter apparatus as claimed in claim 14 or claim 15 wherein the receiver means is adapted for electronic storage of data from a plurality of said electronic devices.

17. A meter apparatus as claimed in any of claims 14-16 wherein the receiver means is adapted for indirect wireless communication with a first electronic device via a direct wireless transmission through one or more other similar electronic devices.

18. A meter apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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